

What is Claimed is:

1. A current limit circuit for protecting a power converter, the current limit circuit coupled to (1) an inductor through which inductor current flows, the inductor current having instantaneous and average inductor current values; (2) a switch having at least one switch element and a duty cycle; and (3) a filtering component having an adjustable filtered signal, the current limit circuit comprising:

a steady-state current limit circuit that reduces average inductor current value to a steady-state threshold during a transient phase and regulates average inductor current value approximately at the steady-state threshold responsive to an over-current condition; and

a cycle-by-cycle current limit circuit that commands reduction of instantaneous inductor current value after the instantaneous inductor current value equals or exceeds a maximum instantaneous threshold during the transient phase.

2. The current limit circuit of claim 1, wherein average inductor current value is regulated in steady-state regulation approximately at the steady-state threshold for a duration that is a function of the over-current condition.

3. The current limit circuit of claim 1, wherein the steady-state current limit circuit is configured to adjust the adjustable filtered signal.

4. The current limit circuit of claim 3, wherein the steady-state current limit circuit reduces

average inductor current value by reducing a magnitude of the adjustable filtered signal.

5. The current limit circuit of claim 1, wherein the steady-state threshold is user-programmable.

6. The current limit circuit of claim 5, wherein the steady-state threshold is user-programmable by a programming resistor.

7. The current limit circuit of claim 1, wherein the maximum instantaneous threshold is user-programmable.

8. The current limit circuit of claim 1, wherein the steady-state current limit circuit senses a signal indicative of instantaneous inductor current value when the at least one switch element is conducting current.

9. The current limit circuit of claim 8, wherein the steady-state current limit circuit is configured to sense the signal indicative of instantaneous inductor current value when the instantaneous inductor current value is decreasing.

10. The current limit circuit of claim 1, wherein the cycle-by-cycle current limit circuit senses a signal indicative of instantaneous inductor current value when the at least one switch element is conducting current.

11. The current limit circuit of claim 10, wherein the cycle-by-cycle current limit circuit is configured to sense the signal indicative of

instantaneous inductor current value when the instantaneous inductor current value is decreasing.

12. The current limit circuit of claim 1, wherein the steady-state current limit circuit reduces average inductor current value by reducing the duty cycle.

13. The current limit circuit of claim 1, wherein the cycle-by-cycle current limit circuit commands escalation of instantaneous inductor current value after the instantaneous inductor current value decreases to a minimum instantaneous threshold during the transient phase.

14. The current limit circuit of claim 13, wherein the maximum and minimum instantaneous thresholds are set relative to the steady-state threshold so that average inductor current value during the transient phase is greater than the steady-state threshold.

15. The current limit circuit of claim 13, wherein the minimum instantaneous threshold is greater than the steady-state threshold.

16. The current limit circuit of claim 1, wherein the maximum instantaneous threshold is greater than the steady-state threshold.

17. The current limit circuit of claim 1, wherein the cycle-by-cycle current limit circuit comprises a hysteretic comparator.

18. A current limit circuit for protecting a power converter that delivers output current to a load,

the current limit circuit coupled to (1) an inductor through which inductor current flows, the inductor current having instantaneous and average inductor current values; (2) a switch having at least one switch element and a duty cycle; and (3) a filtering component having an adjustable filtered signal, the current limit circuit comprising:

a steady-state current limit circuit that reduces output current to a steady-state threshold during a transient phase and regulates output current approximately at the steady-state threshold responsive to an over-current condition; and

a cycle-by-cycle current limit circuit that commands reduction of instantaneous inductor current value after the instantaneous inductor current value equals or exceeds a maximum instantaneous threshold during the transient phase.

19. A current limit circuit for protecting a power converter, the current limit circuit coupled to (1) an inductor through which inductor current flows, the inductor current having instantaneous and average inductor current values; (2) a switch having at least one switch element and a duty cycle; and (3) a filtering component having an adjustable filtered signal, the current limit circuit comprising:

an amplifier that generates a control signal that commands reduction of average inductor current value to a steady-state threshold during a transient phase and regulation of average inductor current value approximately at the steady-state threshold responsive to an over-current condition; and

a cycle-by-cycle comparator that commands reduction of instantaneous inductor current value after the instantaneous inductor current value equals or exceeds a maximum instantaneous threshold during the transient phase.

20. A current limit circuit for protecting a power converter, the current limit circuit coupled to (1) an inductor through which inductor current flows, the inductor current having instantaneous and average inductor current values, and (2) a switch having at least one switch element and a duty cycle, the current limit circuit comprising:

a filtering component having an adjustable filtered signal;

an amplifier that adjusts the stored energy during an adjustment period responsive to average inductor current value being greater than a steady-state threshold; and

a cycle-by-cycle comparator that commands reduction of instantaneous inductor current value after the instantaneous inductor current value equals or exceeds a maximum instantaneous threshold during at least part of the adjustment period.

21. A power converter comprising:

an inductor through which instantaneous inductor current flows;

a switch having at least first and second active switch elements, the first active switch element configured to be turned ON to conduct

increasing instantaneous inductor current, the second active switch element configured to be turned ON to conduct decreasing instantaneous inductor current; and

a comparator coupled to the second active switch element to sense a signal indicative of instantaneous inductor current during at least a portion of the time the second active switch element is ON, the comparator configured to command the second active switch element to be kept ON for a duration after instantaneous inductor current exceeds a maximum instantaneous threshold, the duration being a function of a period of time in which instantaneous inductor current compares in a predetermined manner to a minimum instantaneous threshold.

22. The power converter of claim 21, wherein the comparator is a hysteretic comparator that compares the signal indicative of instantaneous inductor current to signals corresponding to the maximum and minimum instantaneous thresholds.

23. The power converter of claim 21, further comprising a second comparator that compares the signal indicative of instantaneous inductor current to a signal corresponding to the minimum instantaneous threshold.

24. A method for limiting current in a power converter, the power converter having (1) an inductor through which inductor current flows, the inductor current having instantaneous and average inductor current values; (2) a filtering component having an adjustable filtered signal; and (3) a switch having at

least one switch element and a duty cycle, the method comprising:

reducing average inductor current value to a steady-state threshold during a transient phase responsive to an over-current condition;

regulating average inductor current value approximately at the steady-state threshold; and

reducing instantaneous inductor current value after the instantaneous inductor current value equals or exceeds a maximum instantaneous threshold during the transient phase.

25. The method of claim 24, wherein regulating average inductor current value approximately at the steady-state threshold comprises regulating average inductor current value approximately at the steady-state threshold for a duration that is a function of load current demand.

26. The method of claim 24, wherein reducing average inductor current value to a steady-state threshold comprises adjusting the adjustable filtered signal.

27. The method of claim 26, wherein adjusting the adjustable filtered signal comprises sinking current.

28. The method of claim 26, wherein adjusting the adjustable filtered signal comprises sourcing current.

29. The method of claim 26, wherein regulating average inductor current value comprises regulating the adjustable filtered signal approximately at a level indicative of the steady-state threshold.

30. The method of claim 24, further comprising user-programming the steady-state threshold.

31. The method of claim 30, wherein user-programming the steady-state threshold comprises selecting a programming resistance.

32. The method of claim 24, further comprising user-programming the maximum instantaneous threshold.

33. The method of claim 24, further comprising sensing a signal indicative of instantaneous inductor current value when the at least one switch element is conducting current.

34. The method of claim 33, wherein sensing a signal indicative of instantaneous inductor current value comprises sensing a signal indicative of instantaneous inductor current value when the instantaneous inductor current value is decreasing.

35. The method of claim 24, wherein reducing average inductor current value comprises reducing the duty cycle.

36. The method of claim 24, further comprising increasing instantaneous inductor current value after the instantaneous inductor current value decreases to a minimum instantaneous threshold during the transient phase.



37. The method of claim 36, wherein the maximum and minimum instantaneous thresholds are set relative to the steady-state threshold so that average inductor current value during the transient phase is greater than or equal to the steady-state threshold.

38. A method for limiting current in a power converter that delivers output current to a load, the power converter having (1) an inductor through which inductor current flows, the inductor current having instantaneous and average inductor current values; (2) a filtering component having an adjustable filtered signal; and (3) a switch having at least one switch element and a duty cycle, the method comprising:

reducing output current to a steady-state threshold during a transient phase responsive to an over-current condition;

regulating output current approximately at the steady-state threshold; and

reducing instantaneous inductor current value after the instantaneous inductor current value equals or exceeds a maximum instantaneous threshold during the transient phase.

39. A method for limiting current in a power converter, the power converter having (1) an inductor through which inductor current flows, the inductor current having instantaneous and average inductor current values; (2) a filtering component having an adjustable filtered signal; and (3) a switch having at least one switch element and a duty cycle, the method comprising:

providing the adjustable filtered signal;

adjusting the adjustable filtered signal to reduce average inductor current value to a steady-state threshold during a transient phase responsive to an over-current condition;

regulating the adjustable filtered signal approximately at a level indicative of the steady-state threshold to regulate average inductor current value approximately at the steady-state threshold; and

reducing instantaneous inductor current value after the instantaneous inductor current value equals or exceeds a maximum instantaneous threshold during the transient phase.

40. A method for limiting current in a power converter, the power converter having (1) an inductor through which instantaneous inductor current flows; (2) a switch having at least first and second active switch elements, the first active switch element configured to be turned ON to conduct increasing instantaneous inductor current and the second active switch element configured to be turned ON to conduct decreasing inductor current; and (3) a first comparator, the method comprising:

sensing a signal indicative of instantaneous inductor current from the second active switch element during at least a portion of the time the second active switch element is ON;

comparing instantaneous inductor current to a maximum instantaneous threshold;

commanding the second active switch element to be kept ON for a duration after instantaneous inductor current exceeds the maximum instantaneous threshold; and

comparing instantaneous inductor current to a minimum instantaneous threshold in a predetermined manner for a period of time, the duration being a function of the period of time.

41. The method of claim 40, wherein comparing instantaneous inductor current to maximum and minimum instantaneous thresholds comprises using the first comparator to compare the signal indicative of instantaneous inductor current to respective signals corresponding to the maximum and minimum instantaneous thresholds.

42. The method of claim 40, wherein the power converter further comprises a second comparator and comparing instantaneous inductor current to a minimum instantaneous threshold comprises using the second comparator to compare the signal indicative of instantaneous inductor current to a signal corresponding to the minimum instantaneous threshold.